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1899.

ORDINARY MEETING.*

SIR CHARLES A. GORDON, K.C.B, Q.H.P., IN THE CHAIR.

The Minutes of the last Meeting were read and the following elections took place :—

MEMBER :—Professor J. Zimmerman, M.A., D.D., United States.

ASSOCIATES :—Rev. T. B. Angell, D.D., United States; D. Harlowe, Esq., United States.

The following paper was read by the Author :—

ON THE SUB-OCEANIC TERRACES AND RIVER VALLEYS OFF THE COAST OF WESTERN EUROPE. By Professor EDWARD HULL, LL.D., F.R.S., F.G.S. (Late Director of the Geological Survey of Ireland.) (With three Plates.)

PART I. INTRODUCTORY.

IT has been recognised for many years past that the British Isles and adjoining parts of the European continent rise from a submarine platform—generally known as "the 100-fathom platform"—and that this terminates along a declivity more or less steep, descending into very deep water forming the abyssal region of the Atlantic. As far back as 1849, the late Mr. Godwin-Austen described the limits and composition of this platform over its western area off the coast of the British Isles, and showed that it was covered by shingle containing littoral shells, sometimes entire, including *Patella vulgata*, *Turbo*, *Littorina*, etc., far out to sea and at depths of 80 to 100 fathoms; arriving at the conclusion that they at one time formed successive margins of the Atlantic during a period of upheaval, or before the present submergence. Such shingle beaches are well

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* 17th April, 1899. The importance of full consideration by the scientific world of the points brought out in Dr. Hull's paper, has been held to require its early insertion in the Journal.

represented at the Little Sole Bank and the Nymph Bank in lat. 49° N. and long. 10° E.*

In 1853 the late Sir H. T. de la Beche in his *Geological Observer* shows by a map the expanse of the area within the 100-fathom line, which if raised to the level of the sea, as he believed it had been, would represent to the eye little else than a vast plain; and he adds, "if we extend the area to the 200-fathom line it would not be much increased owing to the steep descent of the slope."† This able exponent of geological phenomena indicates also the process of formation of this but very gently sloping shelf, by attributing it to the eroding effects of wave action, and the distributing power of the tides during a period of gradual submergence. The existence of this remarkable platform—established by these early observers—has since been recognised by several writers,‡ and its extension southwards along the coasts of France, Spain and Portugal is thoroughly established. But the real physical base of the declivity forming the margin of the British-Continental shelf has not been indicated by these authors, nor the fact that the shelf is intersected by river channels reaching down to its very base at depths varying from 6,000 to 9,000 feet below the level of the ocean, as I hope to show by means of the soundings on the Admiralty charts of the British Isles and Western Europe. Nor is this at all surprising, seeing that the existence of such physical features at such great depths demands the admission of stupendous changes in the regions here contemplated as regards elevation and depression, such as naturalists might well hesitate to accept unless demonstrated by evidence of the most convincing kind. And, for myself, I fully admit that had it not been for the clear demonstration by several American geologists, but especially by that of the Professor J. W. Spencer, that the bed of the ocean along its western margin has been worn into terraces traversed by old river

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* "The Valley of the English Channel," *Quart. Journ. Geol. Soc.*, vol. vi (1849). Prestwich concurs in this view, *Geology*, vol. i, p. 118.

† *Geological Observer*, 2 Edit., pp. 91–92.

‡ Amongst these may be mentioned Dr. G. C. Wallich, *The North Atlantic Sea-Bed* (1862), Plate XII, Professor Boyd-Dawkins, *Popular Science Review*, October, 1871; Professor T. Rupert Jones, *Rep. Croydon Microscopic Club*, 1877; Professor J. Geikie, *Address Brit. Assoc.*, 1892, and *Proc. Roy. Geog. Soc.*, Sept., 1892; Professor T. McK. Hughes, *Trans. Victoria Inst.*, 1879; A. J. Jukes-Browne, *Building of the British Isles*, 2 Edit.

channels down to depths of several thousand feet below the present level, it would probably not have occurred to me to ascertain whether similar physical features characterise the bed of the ocean along its eastern margin.*

II. MODE OF DETERMINING SUB-OCEANIC PHYSICAL FEATURES.—Isobathic lines (or lines of equal depth), drawn on the charts by the aid of soundings, offer a reliable means for determining the physical features of submerged areas in the same way that contours traced by means of levelling, serve for representing those of the land. When the soundings are sufficiently numerous, as is the case on the Admiralty charts off the British coasts, the isobathic lines may be drawn at short intervals of depth, and the form of the sea-bed may be very accurately drawn in section; but off the coasts of Spain and Portugal, as in the case of Vigo Bay, additional soundings are much to be desired in order to enable us to delineate with sufficient accuracy the contours of the oceanic bed. It may, nevertheless, be affirmed that those shown on the Admiralty charts are quite sufficient to enable us to trace out the main features of the ocean floor; and, in some instances when the coast is approached, with all needful minuteness of detail. For the purpose of this investigation I have found the isobaths of 100, 200, 500, 750, 1,000, and 1,500 fathoms, generally sufficient except in a few special cases where additional contours have been drawn. Beyond the 1,500-fathom contour, the gently sloping floor of the abyssal ocean, formed mainly of "Globigerina ooze," spreads away westward. On the British Admiralty charts, the nature of the sea bottom is frequently indicated along with the depth of each sounding.

III. EXTENT OF THE REGION EMBRACED IN THIS PAPER.—Having already dealt with the tract lying off the British Isles extending from the platform of Rockall round by that of the west coast of Scotland, England and Ireland as far south as the English Channel,† I propose to extend our

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* Spencer, "Reconstruction of the Antillæan Continent," *Bull. Geol. Soc. Amer.*, vol. vi; Warren Upham, "Cause of the Glacial Epoch," *Trans. Victoria Inst.*, vol. xxix, p. 121. Several American geologists, including Dr. Walcott, have given their adhesion to Professor Spencer's views.

† "Further investigations regarding the Submerged Terraces and River Valleys bordering the British Isles," *Trans. Victoria Inst.*, vol. xxx, p. 305.

observations round the coast of France and the Bay of Biscay southwards to the entrance of the Straits of Gibraltar embracing a distance of about 1,500 miles along the coast, containing numerous very interesting features, such as we now meet with on the surface of the land, consisting of terraces, escarpments, and river-valleys.

PART II.

I. THE CONTINENTAL PLATFORM.—This gently sloping terrace, stretching seawards from the coasts of France, Spain, and Portugal, is continuous with that on which the British Isles are planted. As far as I can ascertain it was first indicated in Dr. Stieler's Hand Atlas.* Its margin is shown by the 100–200-fathom contour; but there are no indications given there that it is trenched by channels resembling those of rivers on the land. On the Physical Chart of the World of the "Challenger" expedition, the general form of the British-Continental Platform is approximately indicated by the 1,000–2,000-fathom contours, but the scale is too small to show details, and there are no indications of clefts or river-valleys.† The chart of Perthes seems to have been generally followed by subsequent writers. The newest sub-oceanic map is that of Mr. Hudleston, F.R.S., showing the platform—but not the river-valleys.‡

Opposite the coast of France, at Brest, the platform is about 130 miles in breadth, where it enters the Bay of Biscay; and here, owing to the recession of the coast, the breadth reaches over 100 miles, but becomes gradually narrower southwards. Along the north coast of Spain the platform becomes unusually narrow, averaging only from 20 to 30 miles outward from the coast to its margin. Off Cape Finisterre, and west of the coast of Portugal, the breadth varies from 30 to 40 miles and then gradually increases southwards till, off Cape St. Vincent, it appears to widen out and terminate in a succession of terraces;

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* Published by Justus Perthes. Gotha, 1872.
† Published 1873-6.
‡ *Geological Magazine*, March, 1899, p. 97.

but the soundings are here insufficient to show clearly the physical structure of the ocean-bed. All along this coast the margin of the platform very nearly coincides with the 200-fathom isobathic line.

(*b.*) *Composition of the Floor.*—Throughout the tract above described from the English Channel to the entrance of the Straits of Gibraltar, the floor of the platform is composed of fragmental matter, such as gravel, banks and sheets of sand, clay and occasionally boulders of rock. These materials have been carried down into the sea by the rivers or dislodged from the coast-cliffs, and spread over the floor by tidal currents. Though enclosing molluscs and other animal forms, these materials are essentially different from those which are spread over the floor of the abyssal regions of the ocean consisting mainly of calcareous marl; and thus the great declivity along which the platform breaks off seawards becomes the physical line of separation between the essentially oceanic and essentially littoral deposits.

"*Plane of Marine Denudation*";* *and* "*Base-level of Erosion.*"†—In the platform above described we have an illustration of the former, and in the cliffs which form its boundary along the coast, we have an illustration of the latter. The platform owes its nearly level surface to the action of the sea during periods of emergence and subsequent gradual submergence. The term "plane of marine denudation" is one applied by the late Sir Andrew Ramsay to describe theoretical plane-surfaces of extensive tracts in Wales and elsewhere, which have been subsequently eroded by river-valleys.‡ The British-Continental Platform is an admirable example of one of these, and is still in course of formation along the "base-level of erosion" of the coast cliffs by means of wave and current-action.

II. THE GREAT DECLIVITY.§—I apply this term as it is, in my view, the only fitting one to describe the abrupt descent along which the Continental Platform breaks off and is connected with the vast plain which forms the floor of the

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* Either "plane" or "plain" according as we regard it a mechanical or a physical surface.

† Professor Emmons of U.S.A.

‡ *Physical Geology of Great Britain*, 5 Edit. (1878).

§ The term I had originally employed for this feature was "Grand Escarpment," but in deference to the objections of some geologists I have substituted the above, although "Escarpment" is allowed in this sense in America. Mr. Hudleston calls it "The Sub-oceanic Continental Slope," *Geological Magazine*, March, 1899.

abyssal regions of the ocean. Measured from Rockall in the north (lat. 57° 12′ N.) to Cape St. Vincent it has a length of about 1,500 English miles; but along the coast, about 2,000 miles. Such an oceanic slope if elevated into land would have no parallel in Europe; but, as Professor J. W. Spencer has shown, has its representative in the steep declivity which ranges from Mexico into the United States of America, surmounted by a plateau rising to 8,000 feet above the Gulf of Mexico.* The Great Declivity of the eastern Atlantic is diversified by numerous headlands and bays; while it is also deeply cleft to its very base by channels intersecting the platform for long distances; being, in fact, cañons, or fjords, of the rivers which descended into the ocean when under terrestrial conditions; these will be described further on.

As far as I have been able to determine from the soundings the Great Declivity descends in one continuous sweep from its upper margin to its base at a depth of 6,000 to 9,000 feet below the surface of the ocean. In this respect it differs from its representative on the western borders of the Atlantic, where the descent from the American Continental Shelf into the abyssal regions is accomplished by means of two distinct declivities separated by a broad and well defined terrace, known as the "Blake Plateau."† These differences in the form of the continental slopes on opposite sides of the ocean are illustrated by the following general sections (Figs. 1 and 2).

The base of the Declivity, which in the case of the Vidal Bank off the coast of Scotland corresponds with the 1,000-fathom contour, gradually descends in a southerly direction, so that off the Porcupine Bank it appears to touch the 1,500 contour, giving a total descent of 7,800 feet (1,300 fathoms) from the upper margin to its base. With this general descent the Declivity follows the coast of the Bay of Biscay and that of Spain and Portugal to Cape St. Vincent, beyond which points I have not as yet had opportunity to follow it; we cannot doubt, however, that it is represented off the coast of Africa for some distance southwards.

From the base of the Great Declivity at a depth varying between 1,000 to 1,500 fathoms—the floor of the abyssal

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* Spencer, "Great Changes of level in Mexico, etc.," *Bull. Geol. Soc. Amer.*, vol. ix (1897) ; *Trans. Canadian Inst.*, vol. v.

† So-called by Professor L. Agasssiz, *Two Cruises of the "Blake."*

ocean stretches gradually away westwards to depths of 2,600 fathoms and upwards. The material of which it is composed is mainly of organic origin. In the Bay of Biscay the depth descends to 3,000 fathoms, and the floor consists of "blue and green mud" varieties of the *Globigerina-ooze*, with percentages of carbonate of lime, ranging from 53 to 75;

Fig. 1

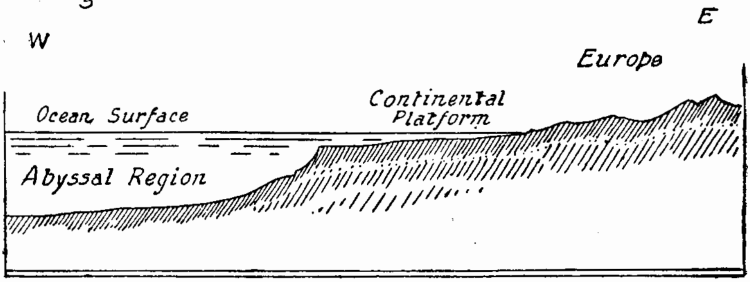
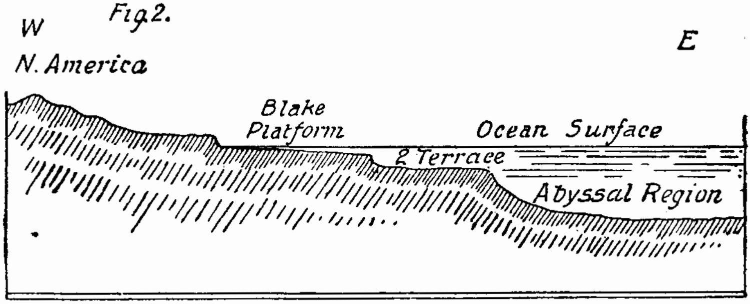


Fig. 2.



Figs. 1 and 2. *To illustrate the difference of outline between the European Continental Terminal Slope and that of the N. American Continent.*

the residue consisting of minute particles of quartz, felspar, augite and volcanic matter.*

III. Slopes of the Great Declivity.—Exception has been taken to the views here advanced regarding the nature and origin of the Great Declivity on the ground that the slopes are extremely slight. This view does not appear to be borne out by the results of actual measurement—which

* Report "Challenger" Expedition, p. 48.

show that the slopes from the edge of the Continental Platform to the base are in general quite comparable with those of land escarpments. For the purpose of determining this point I have drawn by means of co-ordinates where the soundings admit, nine sections, and plotted them to a natural scale. In doing so I have only taken those of the outer slopes; but if I had also included the sides of the cañons, or old river-valleys, the results in the direction of steepness would have been much greater. As a general conclusion we may take the average slope at 13° to 14°; varying from 5° to 36° or even more. The walls of the submerged cañons or river-valleys are, however, often precipitous, sometimes vertical, faces of rock. The following table shows the results of the soundings:—

TABLE SHOWING APPROXIMATE SLOPES OF THE GREAT DECLIVITY.

No.	Position.		Fathoms in depth.	Distance from edge to foot in miles.	Approximate slope.	Approximate angle of slope.
1	Vidal Bank,	Lat. 55° N.	900	10	1 in 10	5 degrees.
2	" "	" 54° N.	800	5	1 in 5·5	10 "
3	La Chapelle Bank,	" 47° 30′	900	4·5	1 in 4	16 "
4	Bay of Biscay,	" 47° 20′	1,000	15	1 in 13	4 "
5	Promontory of Brest	" 48° 10′	1,300	4	1 in 2·6	21 "
	" "	" 46° N.	1,200	7	1 in 5	11 "
6	Off C. Penas,	" 44° 20′	1,300	5	1 in 3·4	17 "
7	Off C. Ortegal,	" 44° 5′	1,300	4·5	1 in 3	18 "
8	Off C. Torinana,	" 43° 4′	1,300	2·5	1 in 1·6	36 "
9	Off Oporto,	" 41° 5′	1,300	12·5	1 in 8·5	7 "

Off the coast of Spain and Portugal the descent to the 1,000 fathom contour is generally steep and is varied by numerous bays and headlands; but owing to the fewness of the soundings, as for example off Vigo Bay, the features cannot be traced with that degree of detail which is possible in the British and French waters. Off the north coast of Spain the declivity is characterised by several precipices comparable with some amongst the Alps and other mountain chains. Thus off Cape Bidio, there is a descent of about 8,000 feet in four miles; another off Cape Ortegal of about 13,000 feet in the same distance; a third off Cape Toriñana of about 9,750 feet, where the 200 fathom contour is very nearly over a sounding of 1,825 fathoms. These nearly sheer descents have their counterparts in those which bound the submerged terraces off the coast of North America and the West Indian Islands.*

It is not to be supposed, however, that the descent from the edge of the platform to the base was by any means uniform. The isobathic lines indicate great variations in the amount of slope—with (in some cases) wide terraces intervening between steep, perhaps precipitous, descents. This is what might be expected as the result of wave action along emerging or subsiding land, accompanied by occasional pauses in the movement, and amongst rocks varying in character and hardness.†

Thus off Cape Prior (lat. 44° 10′ N. and long. 9° W.) the contours clearly indicate wide terraces ending off in steep descents at the margin of the oceanic floor, and similar features are observable both in the region lying to the north of the grand cañon of the Adour in lat. 44° N. and long. 3° W.—and off Cape St. Vincent. A larger number of soundings are, however, required in order to arrive at a better knowledge of these details.

As far as I have been able to judge from the soundings a complete change in the form of the oceanic floor takes place between Cape St. Vincent and the Straits of Gibraltar. The Grand Declivity appears to widen out, and to give place to a gradual slope descending from the margin of the land to the abyssal regions of the ocean, probably in a succession of steps or terraces.

IV. Submerged River-Channels or Cañons.—It is owing to the existence of river-channels, sometimes traceable up to those now entering the ocean from the land, that we are enabled to arrive at the conclusion that the ocean-bed was formerly, to some extent, a land surface; and it is also by means of these features that we can ascertain the extent of the former emergence. It is only on emergent lands that rivers can wear down their channels; for once they have entered the sea their currents are checked, or

* See map to Professor Spencer's "Reconstruction of the Antillean Continent," *Bull. Geol. Soc. Amer.*, vol. vi, 1895; *Geol. Mag.*, Nov. 1898, Plate, p. 515.

† It must be recollected also, that the effect of wave-action on the subsiding escarpment would have been in the direction of reducing the amount of the original slope which after the maximum emergence may have been much greater than at present.

annihilated, and their erosive action ceases.* Hence if the soundings enable us to trace out channels of rivers descending from comparatively shallow levels to those of great depth, we are driven to the conclusion, however unexpected, that the sea-bed was elevated into land to that extent; and the "base-level of erosion" (or ultimate depth) is shown by the position of the *embouchure* where the channel opens out on the abyssal floor. In the region we are now considering, this depth reaches as far down as the 1,500 fathom contour; in other words, 9,000 feet below the surface; possibly a little over this.

I now proceed to give some account of the principal submerged river-channels themselves, from the north to the south of the region here under consideration, taking in succession those of France, the Bay of Biscay, and the coast of Spain and Portugal.

Having on a former occasion endeavoured to describe the sub-oceanic river-channels to the west of the British Isles as indicated by the Admiralty soundings, it is only necessary for me to refer the reader to the paper in question†; but I propose to make an exception in favour of the "English Channel River" for the reason that it in part belongs to the continental system and should not be omitted from a treatise dealing with submerged continental streams. It is also one of peculiar interest, and its existence has been recognised by Professor Boyd-Dawkins, Mr. Jukes-Browne, and Professor T. Rupert Jones definitely.

(*d.*) *The English Channel River.*—This channel may be traced at intervals from the Straits of Dover in a nearly straight course to its embouchure in long. 8° W. between walls of rock about 4,000 feet in height. After passing through a deep cañon for a distance of 80–90 miles it received the streams draining the south of England and the north of France, including the Seine, Somme and Rance. Between the Devon and Dorset coast on the north, and the Channel Islands on the south, its course is clearly defined on the Admiralty Chart, by the channel marked as "The Hurd Deep," which is traceable for a distance of 70 miles, with a breadth of about four miles, and a maximum depth of 60 fathoms, or 360 feet, below the general floor of the sea-

* It was largely from this consideration that Professor Spencer was able to demonstrate the former great elevations of the American and West-Indian lands and adjoining ocean-bed.

† *Trans. Vict. Inst.*, vol. xxx (1896–7).

bed at that place. Owing to this part of the old channel lying in the line of the present tidal currents where they are very swift (from eight to nine miles per hour), the channel has been kept clear; while above and below, where the shores of the English Channel recede, the silting has nearly obliterated the course of the original stream.*

V. THE SUBMERGED RIVER-CHANNELS OF THE BAY OF BISCAY.—Still more remarkable, than those already described, are the submerged river-channels of the Bay of Biscay. Those of the Loire, Adour, Caneira are the most important; but besides these are several bays, trenching deeply into the Continental Platform which were clearly the embouchures of streams the upper channels of which cannot now be definitely determined from the charts.

(*a*.) *The Loire.*—In the case of the Loire, the Continental Platform is so broad, about 100 miles, and the river-channels have been apparently so much silted up, that there is difficulty in tracing the connection of the cañon, which, from its position may be supposed to have belonged to this stream, with the Loire itself. Indications of a channel may be observed, from the soundings, S. of Belle Île, and again at a distance of 50 to 60 miles further W. in long. 4° 10′ W.; and from this point to long. 5° 30′ W.; lat. 47° 10′ N., where the cañon is fully developed, the channel may be traced continuously by the depression in the soundings below the general floor of the Platform. Here it takes the form of a double cañon (see Plates I and III), with which it passes down to the abyssal floor at a depth of about 1,500 fathoms. This bifurcation of the channel on reaching the edge of the oceanic slope is not uncommon in the case of several of the larger river-channels such as those of the Adour and Tagus.

(*b*.) *The Gironde.*—A well-defined bay pointing N.E. breaks through the Great Declivity in long. 2° 40′ W.; and lat. 44° 55′ N., which I have inferentially connected with the above-named river, distant about 70 miles; but the soundings are not sufficiently numerous to enable us to follow the connecting channel across the wide expanse of the Platform. As this large river must have entered the ocean somewhere about this position, the inference seems justifiable.

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* "The Hurd Deep" was so called by Captain Martin White, who sounded over it, after the hydrographer of the day, Captain Hurd, *anno* 1810, as I am informed by Admiral Sir William Wharton, F.R.S. (4th May, 1898).

(*c.*) *The Adour.*—Of all the sub-oceanic river channels to be met with along the coast of Western Europe, none are so strikingly developed as that of the Adour. This fine river has its sources amongst the highest valleys of the central Pyrenees and enters the ocean at the base of this range near Bayonne. It is unique in this respect, that its submerged channel is continuous with the existing stream from its present mouth to its ancient embouchure at a distance of about 100 miles from the coast of France, and the channel is recognised on the Admiralty chart for some distance from the shore under the name of "La Fosse de Cap Breton."* This channel reaches a depth of 175 fathoms (1,050 feet) at a distance of five or six miles from the shore, and 117 fathoms (702 feet) below the surface of the Platform. At 15 miles from the same point, another channel joins that of the Adour on the south side, and from this point it rapidly deepens, assuming the form and features of a grand cañon, bounded by steep, sometimes precipitous, walls of rock from 4,000 to 6,000 feet in height, and ultimately opening out on to the floor of the ocean at a depth of about 1,000 fathoms (or 9,000 feet).

A few miles above the embouchure the channel bifurcates (Plate I), the two arms embracing a tract (once doubtless an island) of shallower ground; but the arms ultimately converge on the floor of the abyssal ocean. Between the cañon of the Adour and the coast of Spain to the south, the continental shelf is remarkably narrow, ranging in breadth from 6 to 20 miles, and is indented by several short but deep bays or ravines along which, we may well believe, streams descended from the northern slopes of the western Pyrenees in a succession of rapids and cascades, of which the Rio de Bilbao was doubtless one of the most important. Several branching cañons with their existing streams on the mainland are clearly defined by the contours as shown in Plate I. At the period when all these features were sub-ærial, and when the Atlantic waters washed the base of the Grand Declivity, the scenery of the cañon of the Adour must have resembled in no small degree that of the

* M. Elisée Reclus abandons the attempt to explain the origin of this remarkable "gulf" when he says :—

"But how can we explain that singular gulf which extends immediately in front of Cape Breton on the Coast of Landes? Ought we to attribute its formation to the meeting of the tides, which takes place in the channel of the Gulf of Gascony? This is a question which it is not yet possible to decide."—*The Ocean*, Section I., p. 7. The author claims to have solved the problem which Reclus relegates to the future!

minor cañons of Western America, with the addition of a mountain range, probably snow-clad from foot to summit, in the background, and a great ocean stretching away indefinitely along the front. No scenery at all comparable, except perhaps in western Norway, is now to be found in the European area.

Were there no other sub-oceanic channels throughout the whole region here under review than that of the Adour it would of itself be sufficient to demonstrate its own fluviatile origin and that of all the others here described. For what are the characteristics of a river-valley draining a plateau and adjoining regions? They are: first, a continuous deepening of the bed of the channel in the direction of the outlet; second, continuous widening of the channel in the same direction; third, a winding course; fourth, lateral tributaries descending on one or other of the sides to join the main stream. All these characterise the sub-oceanic channel of the Adour. On the other hand, they are not characteristic of seismic fissures, or of fissures formed by faults or any other process with which we are acquainted on the land surface. We are familiar with valleys with similar characteristics, but waterless, entering the great valley of the Nile or the shores of the Red Sea, or traversing the region of Arabia Petræa and Southern Palestine, where rainfall is either absent or only intermittent; but we do not hesitate to recognise in them the channels of former streams and rivers, though they are now dry; and not less certain is the nature of these sub-oceanic channels now covered by the waters of the Atlantic, such as those of the Loire, Adour, Douro, and Tagus. No other theory than that here advanced will, I venture to hold, serve to explain their origin and presence under the waters of the ocean.

VI. The Submerged River-Channels off the Coast of Spain and Portugal.—The western submerged escarpment off the shore of Spain and Portugal is characterised by several remarkable river-channels and cañons, of which the most important are those of the rivers Caneira, Arosa, Lima, Douro, Mondego, and the Tagus; besides these there is a grand cañon to the north and west of Cape Carvorino (lat. 39° 30′ N.) which may have been the combined channel of two or three now unimportant streams; we shall consider these in their order of succession from north to south. (Plate II.)

(*a.*) *The Caneira.*—A short, but well defined cañon indents the Great Declivity in long. 5° 40′ W. opposite Cape Penas.

In a distance of about 20 miles, it descends from the plain of the Continental Shelf at 200 fathoms to a depth of 1,380 fathoms, having made a bend westwards about half-way down from the apex to the embouchure. The direction of this indentation points towards the mouth of the river Caneira, though the soundings are insufficient to indicate the connecting channel.

(*b.*) *The Arosa.*—This stream probably formed a junction with the river Lerezo Veda before entering the head of the deep and wide cañon which descends from the Continental Platform at the 200-fathom line and opens out on the deep ocean at about the 1,000-fathom line, after a course of 35 miles. in long. 9° 45′ W. and lat. 42° 35′ N. The form of the contours indicate the occurrence of wide platforms bounded by cliffs on either side of the cañon.

(*c.*) *The Lima.*—The platform along this part of the coast being narrow, the head of this cañon (long. 9° 5′ W.) approaches to within 20 miles of the mouth of the Lima at Vianna. At its upper part the cañon is narrow, and descends within a distance of 10 miles to a depth of 1,137 fathoms (6,822 feet) below the surface of the ocean; or 5,622 feet below that of the margin of the platform; absence of soundings prevent any attempt to connect the cañon with the river itself across the platform, but there can be little doubt of the continuity of the channel.

(*d.*) *The Douro.*—The decisive bend inwards of the 200-fathom contour for a distance of 8 or 10 miles opposite the mouth of this river leaves no doubt that we are here in the presence of its submerged channel, and the curves of the 100 and 50-fathom contours enable us to trace the channel across the platform to a distance of only 14 miles from the mouth of the river itself below Oporto. Owing, however, to the absence of soundings in the deeper portions of the sub-oceanic bay, the exact form of this part of the channel cannot be determined, but sufficient remain to show that the river formerly entered the outer ocean through a wide bay and rapid descent at a depth of about 1,500 fathoms.*

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* The fewness of the soundings in some parts of the ocean-bed off the coasts of Spain and Portugal makes the attempt to restore the old river channels the more difficult. I have been favoured by H.S.H. the Prince of Monico with the tabulated results of a large number of soundings made during the years 1885–1888 and 1891–1896 during cruises in the "Hirondelle" and "Princess Alice" off these coasts, but I have not yet found time to protract them on to the charts (1899).

(*e*.) *The Mondego*.—(Plate III.) At a distance of about 35 miles from the coast of Portugal at Palleiros de Mira (lat. 40° 30′ N., long. 9° 25′ W.) there occurs a short, narrow, but remarkably deep, cañon, cutting for a few miles into the Continental Platform and bounded on either side by precipices of rock from 6,000 to 7,000 feet in height as if seen from the base. The bottom of this cañon, indicated by the sounding, "1170" fathoms, is only about 8 miles from its apex: so that the fall must have been at the rate of 752 feet per mile, suggesting a series of grand waterfalls, or cascades, rivalling some of the finest now in existence. This cañon is presumably that of the river Mondego, towards the mouth of which it appears to point; but owing to the insufficiency of the soundings over the platform at this place the connection cannot be established. It is possible, however, that this cañon may have also received the waters of the river Vouga which enters the ocean at Barra Nova and has numerous tributaries. Over the area of the platform, there may have been a junction of this stream with the Mondego, the channel of which is now silted up, and thus the indication of a vast mass of water formerly descending through the cañon, which its profundity suggests, may be explained.

(*f*.) *Cañon off Cape Carvoeiro*.—A profound and well-defined cañon indents the Great Declivity off the coast of Portugal near Cape Carvoeiro, in lat. 39° 30′ N., but which is remarkable for the fact that it does not appear to be directly connected with any important river now descending from the adjoining lands. The apex of the cañon is about 10 miles from the coast at Point Nazareth; and several minor streams, of which the largest is the Vieira, probably united over the surface of the platform to form a sufficient body of water to erode the channel we are now considering. From its apex at the 100-fathom line to its embouchure at a depth of 1,500 fathoms, the length of the cañon is 25 miles, and along its southern margin it was hemmed in by precipices of rock several thousand feet in total depth. The most precipitous part is just to the north of Burling Island where there is a nearly sheer descent of about 5,000 feet. In Plate III, I have drawn sections across this cañon at three successive intervals from the higher to the lower levels.

(*g*.) *The Grand Cañon of the Tagus*.—(Plates II and III.) No doubt can be thrown on the identity of the submerged channel of the chief river of the Peninsula as its apex is directly in front of the mouth of this river at a distance of only five or six miles immediately south of Cape Razon. Like several of the cañons of the larger rivers already described—that of the Tagus is characterised by a double outlet, forming in plan a Delta. After descending from its apex for a distance of 35 miles in a westerly direction, and to a depth of 600 fathoms, the channel divides; one branch, which is the deeper, continuing very much in the same direction; the other, sweeping round in a semicircle to the north-west, and ultimately entering the deep ocean at a distance of about 15 miles from the mouth of the former channel. There is thus enclosed a large isolated tract—the highest part of which rises to within 66 fathoms of the present surface of the ocean. Towards the mouths of these channels the waters of the old Tagus must have entered the ocean in a series of cascades with a total descent of over 5,000 feet within a distance of about six or seven miles;* and considering the vast volume of water brought down by the Tagus at the present day, such a series of falls must have been grand in the extreme, because to the present volume of water must be added that of the Platform itself.

Other submerged channels of minor importance might be referred to, but the above will probably be considered sufficient to give some idea of the magnitude and grandour of the features now lost to view beneath the waters of the ocean—but happily capable of being "summoned from the vasty deep" and idealized by means of the sounding line!

VII. ISOLATED ROCKS AND SEA-STACKS.—Amongst the physical features by which the Great Declivity was diversified the most conspicuous were probably the isolated rocks and sea-stacks which rose from the ocean floor. One of these occurs about 36 miles off Cape Razo in the submerged valley of the Tagus, rising from 500 fathoms of water with the summit 110 fathoms; its height was therefore 2,340 feet. (Plate III.)

PART III.

I. GEOLOGICAL AGE AND MODE OF FORMATION OF THE SUBMERGED PHYSICAL FEATURES.—The fact that the submerged river-valleys are in most cases merely prolongations of those of the adjoining lands is a sufficient indication that the physical features above described are geologically of

* The soundings show a descent from 600 to 1,200 or 1,300 fathoms.

modern age; in other words not earlier than the Middle Tertiary period. It is generally recognised that the physical features of the British Isles and Western Europe received their more definitive form and outline during the Mio-Pliocene stages; in the Alps, in post-Miocene times.* Though the general depression and partial submergence of the existing lands in the Cretaceous period gave place to considerable elevation accompanied by denudation at the commencement of the Eocene period—it was not till after the succeeding Miocene stage that the present sculpturing of the features of the land was fully developed; this process was continued into the Pliocene and post-Pliocene times. It was *then* that the hills, valleys, and river-channels assumed the definite forms and arrangement, which they retain at the present day, and it was, consequently, during this long-continued period that the submerged physical features—the escarpments and river-channels—continuous with those of the land, received their definite outline and direction. This observation applies especially to the south and east of England where the more recent geological formations are to be found.

This view is in harmony with those arrived at by the American observers of these phenomena along the eastern coasts of America and the Antilles. Nor must the biological evidence of recent continuity all round the submerged platform, be overlooked. The flora of the south and west of Ireland gives evidence of a former connection with that of Spain and the south of Europe, as was long since pointed out by the late Professor Edward Forbes, while the identity of the fauna and flora of Iceland with that of Scotland, points to a similar land connection in very recent times, notwithstanding the depression of 550 fathoms (3,300 feet), by which the connecting platform is traversed; as shown by the "Challenger" soundings.† The uprise in recent times of the bed of the North Atlantic to an extent of over 3,000 feet, is absolutely proved on biological grounds. Dr. Wallace includes Iceland in his Palæarctic Region, which embraces the British Isles and North Western Europe.

* See sections across the Alps in various positions by Professors Albert Heim, Carl Schmidt and H. Schardt in *Livret-Guide Géologique, dans Le Jura et Les Alps de la Suisse*, Lausanne (1894).

† "Physical Chart of the world," "Challenger" Report, 1873–6; also, Hudleston, "Eastern Margin of the North Atlantic Basin," *Geological Magazine*, March, 1899 (Plate).

It now only remains for me to endeavour to explain the process by which, as we may conjecture, the physical features under the waters of the Atlantic were developed.

II. MODE OF FORMATION OF THE SUB-OCEANIC FEATURES.—It need scarcely be observed that there is extreme difficulty in the endeavour to sketch out the *modus operandi* according to which the physical features here described were produced. To begin with, we are ignorant, to a great extent, of the form and conditions of the oceanic bed at the commencement of the Tertiary period. During the Cretaceous period there was wide prevalence of oceanic conditions and great depression of the land. With the introduction of the Tertiary period, elevation of the land commenced, becoming accentuated throughout the Mio-Pliocene periods, and probably attaining its maximum result at the commencement of the Pleistocene or Glacial epoch.* The initial effect of the emergence on a surface gradually sloping down from the emergent lands to the abyssal regions of the ocean, would be the formation of "a plane of marine denudation," to use the phrase of the late Sir Andrew Ramsay. This gradually sloping plane, levelled and eroded by wave-action during the process of emergence, is now represented by, though not conterminous with, the British and Continental Platform. Ultimately, when the elevation of the sea-bed attained its maximum, and a prolonged pause occurred, wave-action came into full play, cutting back the emergent lands along "the base-level of erosion," a process continued during subsequent subsidence and submergence down to the present day.

Meanwhile the rivers draining the land areas, both present and past, were at work in wearing down their channels through the Continental Platform; channels which, as we have seen, are still traceable by aid of the soundings down to the very base of the Grand Declivity. I regard the long lapse of the earliest glacial period, that of intensest cold and of severest glacial conditions, as that during which both wave-action along the base of the Declivity, and river-erosion over the Platform, were most effective. It was only a

* The researches of the Swiss and German geologists Heim, Baltzer, Schardt, Renevier and others, show that in the Alps and Jura the most stupendous terrestrial movements occurred after the close of the Miocene period, that is during the Pliocene; as Miocene beds, both lacustrine and marine, have been flexured, folded, and uplifted several thousand feet amongst these regions.

question of time; and who that has studied the phenomena of the "Great Ice Age" can doubt that the time was sufficiently prolonged?

2. The process of subsidence, greatest in the middle glacial submergence of these islands, was probably more rapid than that of emergence, though this is open to question. At the present time the ocean waters are still extending their range along the coasts of the British Isles and of Western Europe. *Si monumentum quæris, circumspice.* The south and east coasts of England attest the rapidity of the process.

3. *Nature of the rocks under the floor of the ocean.*—On this point we can only fall back on conjecture, as the sounding apparatus only brings up specimens of the soft superficial deposits, such as sand, clay, or marl, though a general idea of the nature of the solid floor may be gathered from that of the adjoining lands. Dr. J. Joly, F.R.S., has recently invented an apparatus in the form of an electrically driven drill, by means of which cores of solid rock may be hollowed out of the ocean-bed and be drawn to the surface.*

III. CONCLUDING OBSERVATIONS.—Having on a former occasion pointed out how a great uprise of the ocean-bed and adjoining lands on both sides of the Atlantic must have affected the climatic conditions of these regions to the extent of bringing about glacial conditions in these Isles,† I do not propose to re-open the subject here, further than to observe that we have in this uprise a simple and palpable cause of the general lowering of temperature which took place during the Pleistocene Epoch, and brought about glacial conditions in the northern hemisphere. The prevalence of Arctic conditions brought about by elevation would, it must be remembered, be further accentuated by the uprise of the Antillean continent, as demonstrated by Professor J. W. Spencer, owing to which the Gulf Stream would have been unable to enter the Gulf of Mexico, and would have passed into the North Atlantic with a temperature much lower than at the present day; I have estimated this decrease at 12° Fahr. Such an explanation is in harmony with Lyellian principles, which find in the relative distribution of land and sea the causes which have governed conditions of climate in past time.

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* *Scient. Proc. Roy. Dublin Soc.*, vol. viii, p. 509.

† "Another possible cause of the Glacial Epoch," *Trans. Vict. Inst.*, 1898.

EXPLANATION OF PLATES.

Plate I.

These plates are taken by photographic process from the Admiralty charts—on which I have drawn the isobathic lines of 200, 500, 1,000 and 1,200 fathoms—the first and last of which nearly coincide with the upper edge and base of the Great Declivity (or Escarpment) which separates the Continental Platform from the abyssal region of the ocean. It will be observed how the Declivity is deeply trenched by valleys or "cañons" running for greater or less distances into the Continental Platform—which has a breadth of about 150 miles along the north-east coast of the bay. Through this Platform, the deep submerged channels of the Loire, the Gironde, and the Adour, may be traced by means of the soundings for greater or less distances; that of the Adour through its whole extent of 100 miles.* Along the north coast of Spain, the Platform is very narrow; but is deeply trenched by river valleys which can, with much certainty, be connected with existing streams descending from the Cantabrian High lands; amongst these the cañon of the Caneira is the most distinct; but there are others on a smaller scale entering the Channel of the Adour.

Plate II.

In Plate II, the Platform is continued, and breaks off generally along the 200 fathom contour—which is trenched by numerous channels which can, with more or less certainty, be connected with the existing streams of the mainland of Spain and Portugal. The cañons of the Lima, Douro, the Mondego and the Tagus are clearly traceable; but there are several well-defined and very deep cañons which trench the Great Declivity and the Platform, but which cannot be very clearly referred to existing streams; one of these I have called "the Grand Cañon" in lat. 39° 30′ traceable for 40 miles, and bounded by precipitous cliffs about 5,000 feet in height on the south side. Another short, but very deep cañon occurs in lat. 40° 30′ bounded by precipitous cliffs of about equal height with that of the Grand Cañon—which open out on the abyssal region of the ocean at the foot of the Great Declivity.

The submerged valley of the Tagus, with its remarkable Double Cañon, is admirably defined by the soundings, and can be clearly traced from its ancient *embouchure* up to within about ten miles of the mouth of the existing river, where the channel becomes choked up by sand and silt. It has an entire traceable length of 50 miles by one channel, and of 60 miles by the other. The Continental Platform along this coast has an average breadth of about 35 miles.

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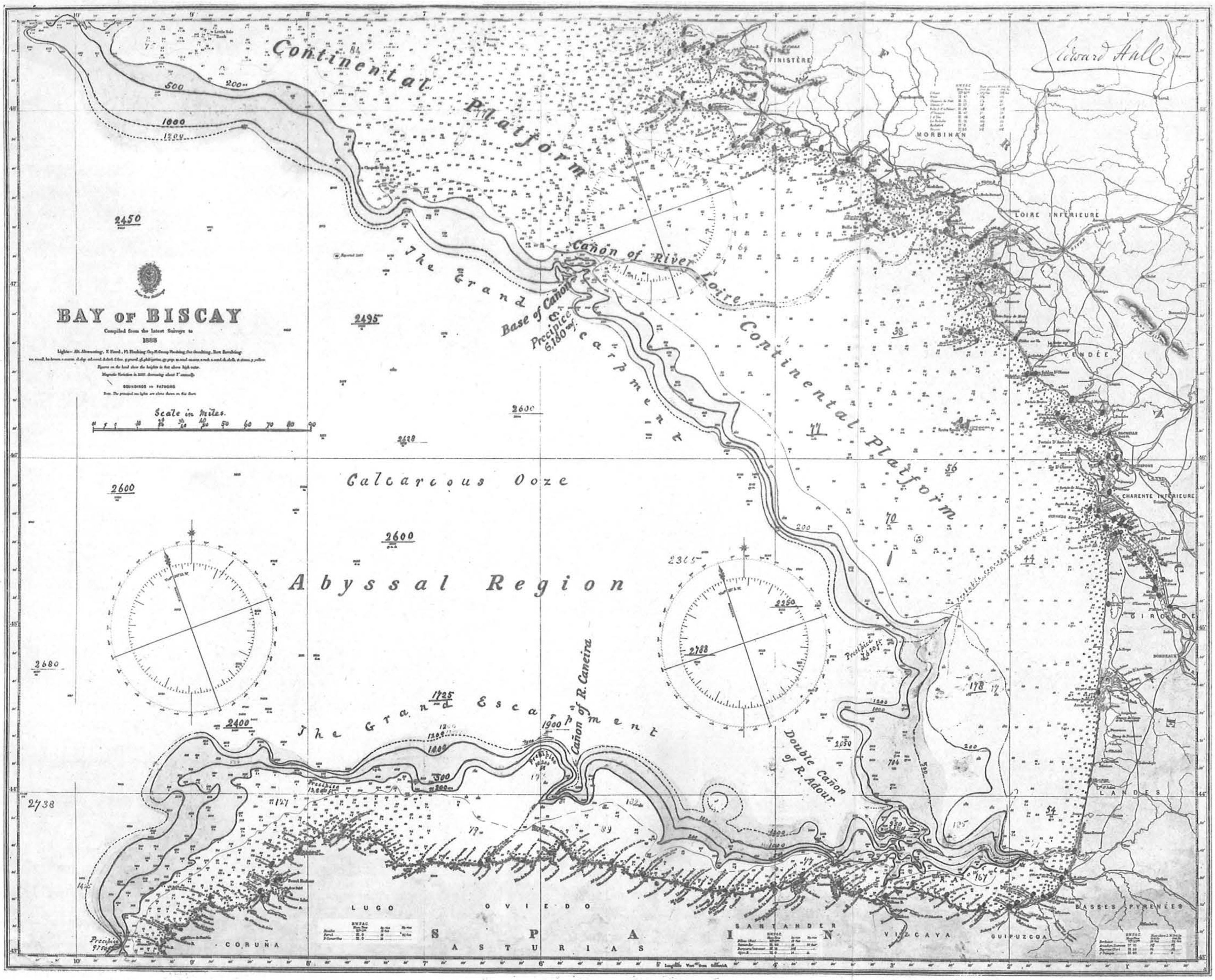
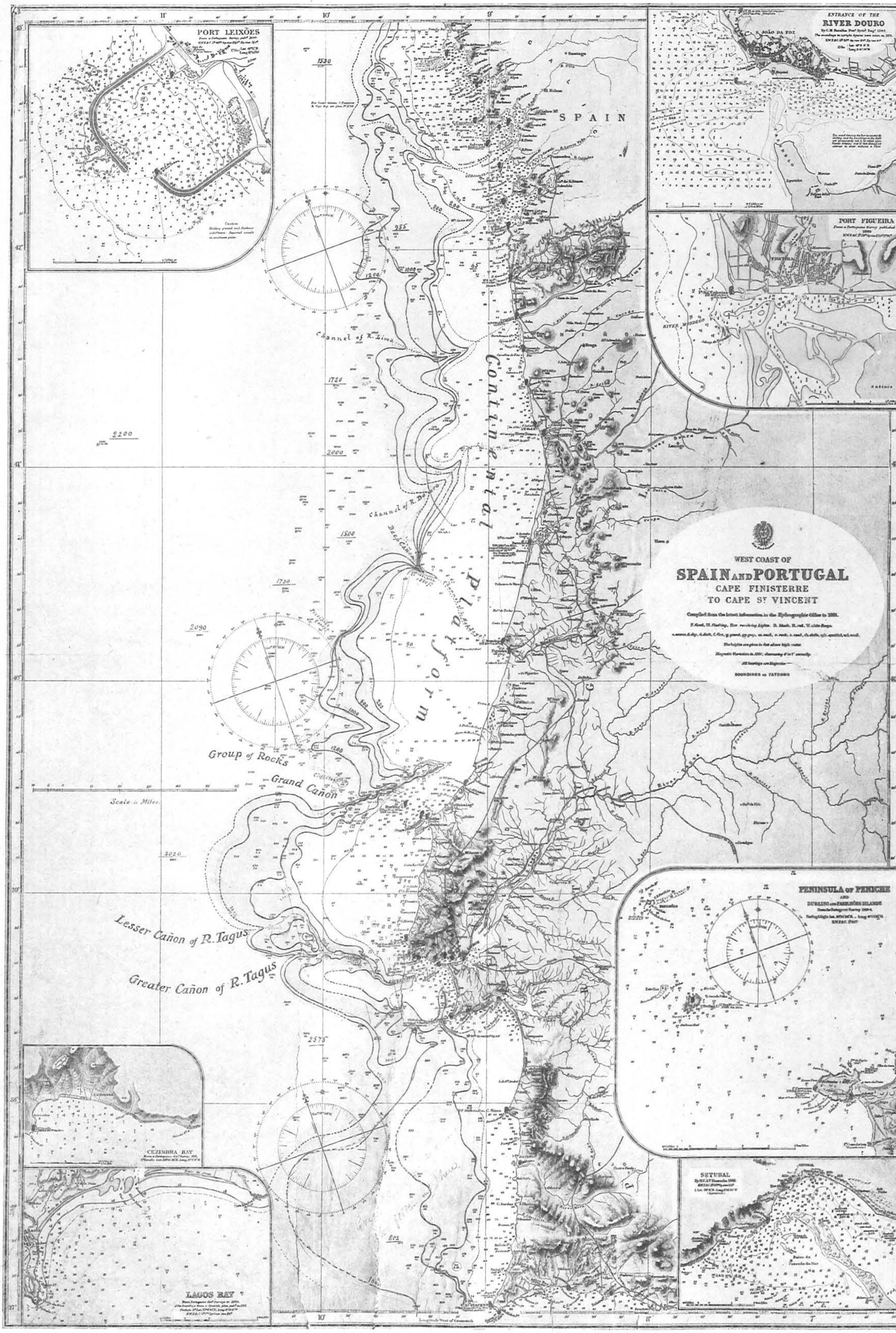
* A plan of the sub-oceanic channel of the Adour on the scale of the Admiralty chart is published in the *Geographical Journal*, March, 1899. The small figures on the maps and sections are fathoms—but unfortunately they are in most cases too minute to be legible.



CONTINENTAL PLATFORM AND RIVER CHANNELS OF BAY OF BISCAY.



CONTINENTAL PLATFORM AND RIVER CHANNELS OF COAST OF SPAIN AND PORTUGAL.

Sections of Sub-oceanic Cañons and Valleys.

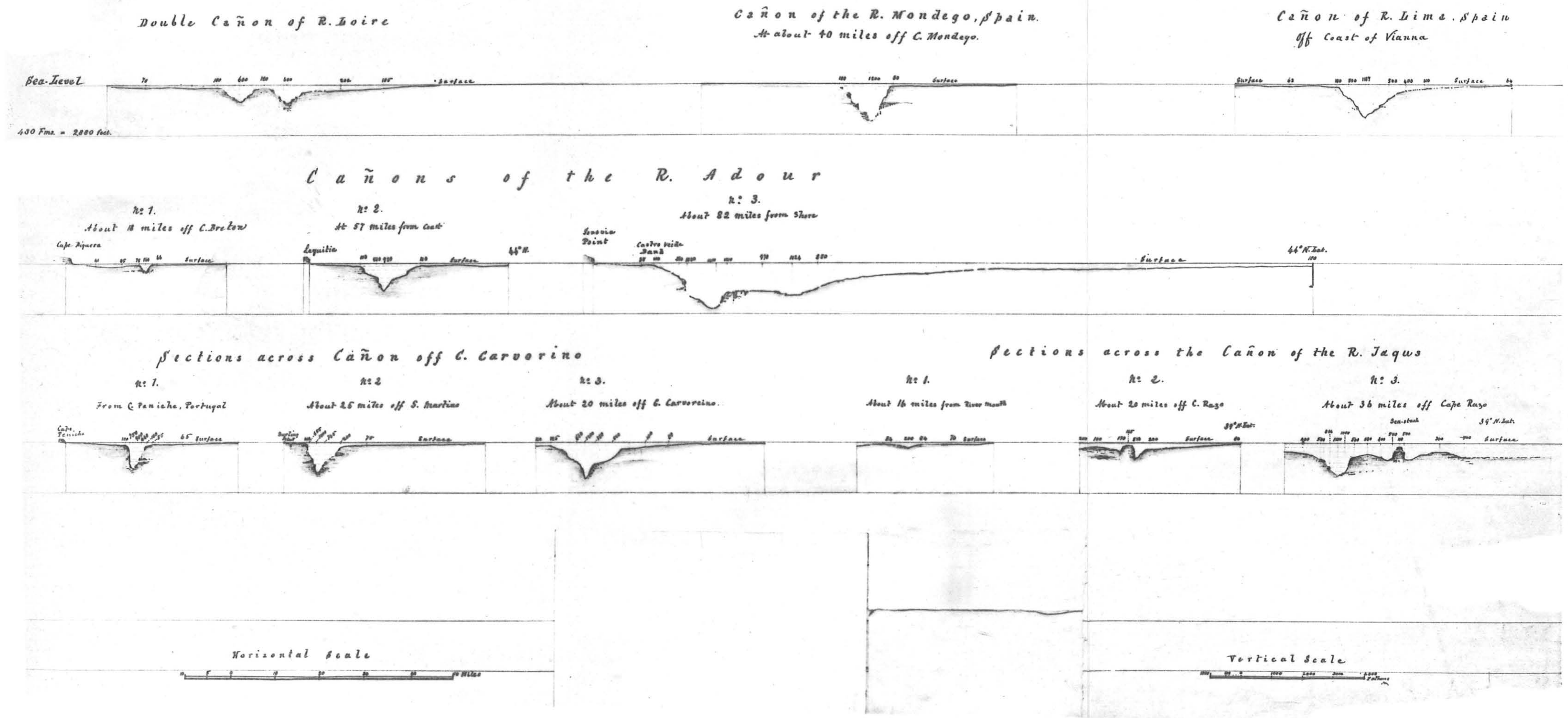


PLATE III.

Little need be said in explanation of Plate III, except that the horizontal and vertical scales are unequal, the latter being (for obvious reasons) exaggerated; but as the soundings are given in fathoms, and may be read by aid of a lens—the determination of the form can be made in each case. These cross sections bring out in a marked manner the forms of the ancient river channels or cañons as they trench deep into the gently sloping plain of the Continental Platform.

DISCUSSION.

The CHAIRMAN (Sir C. GORDON, K.C.B.).—Like myself, all must have followed the author's arguments with great interest and desire to join in according him a vote of thanks. (Cheers.)

Professor ETHERIDGE, F.R.S.—I need hardly say that I am pleased to hear this paper by Dr. Hull, but it is one *not* easily discussed. Its statements are not even easily questioned; few are aware of the amount of labour involved in tracing and determining these great depths, and the involved results placed in that form, for popular exhibition and with scientific description. Few are aware of the labour and patience required to examine and plot out over the Admiralty sheets and the soundings which occur by thousands along our shores and over the deep sea bottom, both British and Continental, then estimating the varying depths to the old and now submerged condition of the river channels ranging from Cape Finistere to near Gibraltar or the entrance to the Mediterranean. These river channels and the "continental platforms" from which the numerous rivers take their rise were discussed by Professor Hull, and compared with the remarkable researches carried on along the eastern side of North and South America as far as the Mexican Gulf, and so ably discussed in his paper read before this Society in 1898 (see p. 141). It would be difficult to name or point out along the extended French and Spanish coast-line any special point of more interest than another, but the case of the remarkable River Adour, north of the Pyrenees, with its deep cañon, is one of many described by Dr. Hull, illustrating the great depression and physical condition of the submarine area some 8,000 or 9,000 feet deep. These great river courses and changes are not depicted as they should be either on our

British or Continental atlases, hence the value of Dr. Hull's researches, thus making his papers read before the Society of such marked value. I need only mention the old and depressed river-beds of the Shannon on the west coast of Ireland and the Seine in the north of France, amongst others, traceable through dredging and sounding as far as the 100-fathom level, or from 150 to 200 miles from the present coast-line. The sections illustrating the depths to the sea-floor given in this paper, and those in the previous paper on the northern British coast-line, are of the greatest value to physical geography, and should be continued to the south-western extremity of Africa, or from where Dr. Hull left off at the mouths of the Adour and its cañon. It must have struck many others present, the difficulty in following the delicate lines of the sections over the sunken areas shown on the transparency; one good coloured section (which few are more able to do than Professor Hull) would have more clearly illustrated the entire series of the interesting sections, stretching far out from the foreshore to the greatest depth he has depicted; and his present paper being more complicated in construction than in his earlier paper from the Shetlands to Cape Ushant, the contour lines are both more numerous and crowded, and therefore difficult to follow.

We yet want these great facts depicted in our physical atlases, which would more clearly illustrate the value of our Admiralty charts, the reading, meaning, and use of which, with their thousands of soundings or registered depths would lead to the still more profound researches and illustrate the physical history of the submerged—but not *lost*—lands which in some future period may again appear under new and increased grandeur.

General McMahon, F.R.S.—I have had great pleasure in listening to Professor Hull's paper, and I think geologists and physical geographers ought to feel much indebted to him for calling their attention to a subject that hitherto has been much neglected. Professor Hull's paper deals with the Continental Platform and the Great Depression.

As regards the course of rivers on the Continental Platform I think that Professor Hull has proved his case, and I have not seen or heard any valid objections to his conclusions. But when we come to the courses of the rivers in the Great Depression I think the evidence is very much weaker. I think that perhaps the soundings are hardly sufficient to enable us to say that the depressions marked on Professor Hull's map are the courses of old rivers.

Professor Hull's theory involves the supposition that parts now buried 9,000 feet under the sea must have been dry land and must have continued dry land for a very long period indeed, for deep and wide river valleys are not the creation of a day. It indicates the existence of elevated land during long ages, and it would be more convincing if Professor Hull would give us geological evidence to show that such long-sustained elevation of the area concerned occurred before the present depression took place.

Then another even greater difficulty occurs to my mind. The difficulty is entirely in reference to the river courses in the great depressions.

Professor HULL.—Do you mean across the Great Declivity?

General MCMAHON.—Yes. My difficulty is that our rivers have always been, and are still, bringing down enormous volumes of mud with them, and we know that when this comes in contact with salt water, by a sort of quasi-chemical action the mud is precipitated; and the precipitated mud is carried by the currents that sweep up and down our coasts under the influence of the tides and wind until it finds a resting place in some depression. The difficulty that occurs to my mind is how could river valleys have remained for so long a period and not have been filled up by silt, for the effect generally of silt is to fill up and to level every depression? Perhaps Professor Hull can remove this difficulty as he has given so much attention to the subject.

The AUTHOR.—I have to express my great pleasure that my friend Professor Etheridge was able to be present this evening, and I am gratified that he indicates his general assent and approval of my views.

I must say that I am afraid that I have neither time nor opportunity to spend in making large coloured diagram maps of these features. I should be most happy, if any one would undertake to do so, to give him any assistance in my power; but it is quite impossible for me to undertake it.

I think these Admiralty charts are on a sufficiently large scale to show very correctly the sub-oceanic physical features, and with the paper itself will be published these charts taken by a photographic process from the Admiralty charts themselves. I think they are pretty good generally, and when anyone reads the paper with the assistance of these maps he will probably have no difficulty in following the course of these contour lines. The plan of the Adour is the most remarkable of all these river channels from the fact of its running for 100 miles from the very shores of the present coast out into the abysmal ocean. That is shown on a pretty large scale, in fact the same scale as the Admiralty chart.

I am very glad that General McMahon goes so far with me as to admit that these channels can be traced across the Continental Platform. But I do not see how we can stop there unless he refuses to admit that the Continental Platform was elevated to the base of the Great Declivity, as I certainly hold most strongly—you cannot stop at 500 fathoms, or 700 fathoms, or 1,000 fathoms. You must go down to the very base of the declivity in order to restore the former relations of land and sea, and these channels in many cases—certainly in the case of the Adour, the Loire and the Tagus—are most clearly traceable by means of the contour lines down to the very base of the escarpment showing the lowest point at which the ocean washed the coasts of the ancient shore.

Then as regards the time;—I can hardly put any reasonable limit to the time of the Great Ice Age. That was the period, no doubt, of the greatest elevation, for the greatest cold was produced then; and if I am right in assuming that cold was produced by the elevation of the land then it would be at the time of the highest elevation. The results of the Great Ice Age, both in Europe and other countries, are so remarkable that the lapse of time must have been very great, probably quite sufficient to enable the rivers to cut down their channels to the base of the declivity. Then General McMahon says, "Why are not the channels filled up?" I am sorry to say that to a great extent they are filled up by silt spread over the floor. If it were not for that, I believe every one of these river valleys could be traced from its present *embouchure* to its emergence on the floor of the abyssal ocean.

Perhaps I may be allowed to read an interesting note from Dr. Nansen. I sent him a report of my lecture on this subject which appears in the *Geographical Journal*, and he says, "Dear Prof. Hull, accept my most hearty thanks for your kindness in sending me your interesting paper on the sub-oceanic terraces and river valleys off the coast of Western Europe, which I have read carefully, and appreciate very much. Yours very sincerely, (Signed) NANSEN, April, 1899."

The Meeting then terminated.

REMARKS ON THE FOREGOING PAPER.

Professor T. McK. Hughes, F.R.S., writes:—

I wish I could be with you on Monday to take part in the discussion upon my friend Professor Hull's paper. I am very glad to see that he is carrying on his researches into the great movements of the crust of the earth which, as I believe, are the chief cause of climatal change, and the principal factors in all our calculations as to the time required to build up the visible crust of the earth, and also for all our speculations as to the succession of events throughout geologic time in any area. I should like to ask the author one question, and that is whether he thinks there is sufficient evidence to refer the movements to any system in respect of surface direction and whether there is any reason to believe that the surface direction has been distinctly different or approximately the same in successive periods after a reversal of the vertical direction of movement.*

I am especially interested in the bearing of the results recorded by Professor Hull upon the question of the causes of locally recurring Ice ages, which I would refer almost entirely to geographical and not to astronomical causes.

Il Cavaliere W. P. Jervis, F.G.S., Keeper of the Royal Italian Industrial Museum at Turin, writes:—

This second paper by Professor Hull presents like interest to his former one. Both alike open up the way to a vast field of research in geology (and as the basis of great future discoveries therein), physical geography, and in relation to the distribution of land and marine fauna of Upper Tertiary and recent times. Such is the multitude of deductions to be drawn from the subject that there is no lack of matter for the cautious study of many different minds. The real fear is that any should be carried away to form rash generalizations, which are the sunken rocks against which too many strike now-a-days, in their precipitate deductions in similar recondite subjects.

Lest I myself should transgress this precaution I submit a few somewhat bold considerations, in the hope that they may be

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* I fear that I do not see my way to answer Professor Hughes's question without more consideration than I could give at this moment.—E. H.

examined by the members of the Victoria Institute, to see whether they can bear scrutiny, for I consider that they all relate to the subject of the paper.

Characteristics of the Upper Tertiary coast-line of Western Europe.— It is essential to place before one the sheets of the Topographical Atlas of France and the large scale charts of the Atlantic sea-board, including the latter relating to the coast southward to Cape St. Vincent; also the best maps of the north of Spain and the west of Portugal. By the aid of such documents we find that the tract of ocean lying within the bathometrical curve of 200 fathoms pretty well indicates the probable former existence of mere hills, which, previous to their denudation, appear to have been analogous to those still emerged, and like them, of Tertiary origin, along the west coast of France. Within the whole area of the Continental Platform the west coast of France is fringed by a gently sloping sea-bed to the very upper margin of the Grand Declivity. The prolonged action of the currents and waves has here planed away all the pre-existing eminences, filling up all the valleys, with the exception of some traces of those of the principal rivers.

Along the Spanish coast the bathometrical curve of 200 fathoms in the Bay of Biscay, precisely as we might have anticipated, approaches very near to the shore, skirting, as it does, the Cantabrian mountains. The important gaps and indents in the direction of the old coast-line are exactly what are met with in steep mountainous regions, whose base is washed by the sea, and the flanks of which are furrowed by short impetuous torrents.

At the period of greatest emersion the Cantabrian mountains must have been a most important chain, and from the fact of their being but a prolongation of the Pyrenees, and lying in the same axis with them, we might be authorised to consider them as having all belonged to the Pyrenees.

Professor Hull, having described the great European Continental Declivity, all along the eastern shores of the Atlantic, from Rockall to Cape St. Vincent, and summarised the researches of American geologists, who have shown the existence of two escarpments along the western shores of the North Atlantic, from the Gulf of Mexico northwards, all along the sea-board of the United States, it seems quite permissible to infer that *the whole bed of the ocean* included between those shores must have participated *in like manner* in the subsidence. In those days the greatest depth of the North Atlantic Ocean must rarely have exceeded 2,000 fathoms.

There is a most interesting collateral illustration to corroborate the statement that during a period of emergence, the surface of the ocean washed the base of the Great Declivity. Thus, the present course of the Jordan lies below the actual level of the Red Sea. Even the lake of Galilee lies 653 feet below the sea level, and the Jordan, on entering the Dead Sea, which is 1,292 feet below the level of the Mediterranean, finds no outlet. But there is sufficient indication in the line of valleys extending southward, bounded by the precipitous rocks of Mount Seir, that at one time the Jordan discharged itself into the Red Sea, south of Mount Sinai, its former cañon (I use the word cañon, in deference to the author; but greatly object to a superfluous foreign name), now submarine, constituting the Gulf of Akaba. Geologically speaking, I should consider this to be the submerged estuary of the Jordan.

The North Atlantic Ocean cannot be classed among the volcanic regions of the globe, nor does it appear that the *uniform submersion* of its coasts has the very remotest connection with volcanic phenomena. On the other hand, the existence of the magnificent gorge or cañon, along the lower course of the Tagus, now submarine, seems to be confirmed by the fact that, during the earthquake of Lisbon, in 1755, the lower part of the city and quays, forming the frontage of the river, were engulfed in a moment, and that no traces of them were ever found since then. They seem to have been precipitated to the bottom of the cañon. Indeed to such instantaneous circumstance—if accepted as justifiable—I would attribute the telluric commotion which, if not the immediate cause of the Lisbon earthquake, certainly would have imparted to it that intensity which gives it a terrific and tragic precedence over all the earthquakes which have devastated Europe. Full well do I anticipate that I am facing the jeers of hosts of believers in far different causes for the Lisbon earthquake, but Professor Hull has proved to a nicety, that the existence of the great cañon of the Tagus defies contradiction, and perhaps my explanation may be considered as true by many.

Most remarkable is the uniform existence of a steep submarine escarpment, some 1,500 miles long, and of about 800 fathoms in depth, which feature is quite unknown in the northern hemisphere, as far as regards emerged ground. Of course the reader could *never suppose that Professor Hull intended to show that it presented that gentle and regularly curved outline which is somewhat diagrammatically shown even in the most accurate charts*, for the excellent reason that soundings of upwards of 200 fathoms are evidently taken at relatively distant intervals, such being amply sufficient for all practical purposes. Were the same minuteness of detail to be expended in mapping the Great Declivity as is needed for topographical surveys, based on contour lines, we should doubtless learn that the ancient, now submerged, coast-line also presented a well marked curvilinear irregular outline similar to such as those with which we are familiar.

It is not easy to assign, or understand, the determining cause of this great change of level of the North Atlantic Ocean, but it is quite illogical to suppose that such cause, of whatever nature it might have been, should have acted in the same direction all over the globe.

We might attribute the change to the *submergence* of a vast region of the Northern Hemisphere. If so, as I should conceive to be plausible, it is reasonable to conceive the simultaneous *emergence* elsewhere of a region of somewhat comparable extent —probably in the Southern Hemisphere. This problem may be elucidated during the course of next century, especially during the Antarctic polar expeditions.

We might also conceive that in consequence of a regular, slow, progressive change in the axis of rotation of our globe—were that theory to be admitted as tenable—the region under consideration was once situated nearer the then tropical zone, and far nearer the former equator than at present. Need I remind the members that the equatorial diameter of the globe, or any other diameter supposed to be drawn within the tropics, greatly exceeds in length any drawn in higher latitudes, and that it is about 20 miles in excess of the axis of rotation, that is to say the polar diameter?

As a *general rule* the most lofty mountains in the world are situated between the equator and 36°, lesser eminences are met with as high as 43°; Mont Blanc is 46°. This I attribute to centrifugal force. If so, similar results would have been produced in correlation to the axis of rotation, whatever it might have been at the given period. A submergence of 1,000 fathoms having been established as a certainty, it only remains to add that the great regularity of the submerged tract bespeaks the absolutely logical conclusion that it must been the *result of an enormously long, slow action, excluding all notion of paroxysms or other disturbances.*

NOTE.

A valued member, Mr. H. P. Malet, contests the idea of the upheaval of the earth's surface, and quotes, as expressing his views, Dr. J. W. Gregory's statement that "the plan of the earth may be attributed to the continual foundering of the earth's external shell owing to the unceasing shrinkages of its internal mass." Yet, as Professor Hull points out, in reply, no one has expounded more clearly than Sir C. Lyell, that the contraction of the crust—due to internal "shrinkage"—necessarily gives rise to upheaval of the crust at various places. Perhaps Mr. Malet will permit some remarks on this subject, kindly contributed by him, to be considered in the coming session.—ED.